

3. CHEMICAL AND PHYSICAL INFORMATION

3.1 CHEMICAL IDENTITY

Nickel is a transition metal in group VIII of the Periodic Table following iron and cobalt (Cotton and Wilkinson 1980). Its outer shell of electrons has a $4s^2 3d^8$ configuration. While nickel can exist in oxidation states -1, 0, +2, +3, and +4, its only important oxidation state is nickel(+2) under normal environmental conditions.

Nickel forms useful alloys with many metals. It is added to metals to increase their hardness, strength, and corrosion resistance. The most familiar nickeliferous alloys are stainless steel and coinage metal.

Nickel oxide also comes in a black crystalline form that has a slightly higher oxygen content than its formula, NiO (Antonsen 1981). The nickel content of black nickel oxide is 76-77% compared with 78.5% for the more stable green nickel oxide. Nickel sulfate, nickel chloride, and nickel nitrate usually exist as hexahydrates, while nickel acetate is generally in the form of a tetrahydrate. Data on the chemical identity of nickel and important nickel compounds are shown in Table 3-1.

3.2 PHYSICAL AND CHEMICAL PROPERTIES

Metallic nickel is a hard, lustrous, silvery white metal, which in its bulk form is resistant to attack by air and water at ordinary temperatures. However, powdered nickel is reactive in air and may spontaneously ignite.

Nickel has typical metallic properties; it can be readily rolled, drawn into wire, forged, and polished. It is also ferromagnetic and a good conductor of both heat and electricity. Nickel is positioned after hydrogen in the electrochemical series and slowly displaces hydrogen ions from dilute hydrochloric and sulfuric acids. It reacts more rapidly with nitric acid. Nickel is highly resistant to attack by strong alkalis (Hawley 1981). Black nickel oxide readily yields nickel salts

Table 3-1. Chemical Identity of Nickel and Compounds^a

Characteristic	Nickel	Nickel oxide	Nickel sulfate	Nickel chloride
Synonym(s)	CI 77775; Nickel 200; Nickel 201; Nickel 205; Nickel 270; Alnico; NP 2 ^b	Green nickel oxide; nickel monoxide; nickel(II) oxide; bunsenite; CI 77777	Nickel monosulfate; nickelous sulfate; nickel(II) sulfate; nickel(II) salt	Nickel(II) chloride; nickel dichloride; nickelous chloride
Registered trade name(s)	Monel; Inconel; Icoloy; Nimonic; Hastelloy; Udimet; Mar M; René 41; Waspaloy; Raney nickel ^c	No data	No data	No data
Chemical formula	Ni	NiO	NiSO ₄	NiCl ₂
Chemical structure	Ni	Ni - O	$\left[\begin{array}{c} \text{S}^{2-} \\ \\ \text{O} - \text{S} - \text{O} \\ \\ \text{S} \end{array} \right] \left[\text{Ni}^{2+} \right]$	Cl - Ni - Cl
Identification numbers:				
CAS registry	7440-02-0	1313-99-1	7786-81-4	7718-54-9
NIOSH RTECS	QR5950000	QR8400000	QR9350000	QR6475000
EPA hazardous waste	No data	No data	No data	No data
OHM/TADS	7216810	No data	7216811	7217269
DOT/UN/NA/IMCO shipping	UN 2881; nickel catalyst, dry UN 1325; nickel catalyst, spent IMO 4.2; nickel catalyst	No data	NA 9141; nickel sulfate	NA 91329; nickel chloride
HSDB	1096	1664	1114	860
NCI	No data	No data	No data	No data

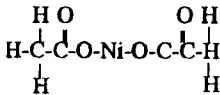
^aAll information obtained from HSDB 1996 except where noted.

^bHawley 1981. Synonyms for nickel refer to different alloys or to different impurity contents.

^cTien and Howson 1981; Winhdolz 1983. Names refer to alloys of nickel. Generally there is a series of alloys with the same trade name (e.g., Monel alloy K-400, Monel alloy K-500).

CAS = Chemical Abstracts Service; DOT/UN/NA/IMCO = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code; EPA = Environmental Protection Agency; HSDB = Hazardous Substances Data Bank; NCI = National Cancer Institute; Ni = nickel; NIOSH = National Institute for Occupational Safety and Health; OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System; RTECS = Registry of Toxic Effects of Chemical Substances

Table 3-1. Chemical Identity of Nickel and Compounds^a (continued)

Characteristic	Nickel acetate	Nickel nitrate	Nickel subsulfide
Synonym(s)	Acetic acid, nickel(2+) salt; nickel diacetate; nickelous acetate; nickel(II) acetate	Nitric acid, nickel(2+) salt, nickelous nitrate; nickel dinitrate; nickel(II) nitrate	Trinickel disulfide; nickel sulfide; Heazlewoodite; nickel sesquisulfide
Registered trade name(s)	No data	No data	No data
Chemical formula	$\text{Ni}(\text{CH}_3\text{CO}_2)_2$	$\text{Ni}(\text{NO}_3)_2$	Ni_3S_2
Chemical structure			
Identification numbers:			
CAS registry	373-02-4	13138-45-9	12035-72-2
NIOSH RTECS	QR6125000	QR7200000	QR9800000
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/IMCO shipping	No data	No data	No data
HSDB	1029	1829	2965
NCI	No data	No data	No data

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on contact with mineral acids, while green nickel oxide is more refractory to solubilization (Sunderman and Oskarsson 1991). The divalent state of nickel forms an extensive series of compounds and is the only important oxidation state in aqueous systems. Other oxidation states occur in special complexes and oxides. In alkaline solutions, nickel(+2) hydroxide can be oxidized to a hydrated nickel(+4) oxide, a reaction used in the Edison storage battery.

Nickel most commonly forms complexes with a coordination number of six. These have an octahedral configuration and are generally green in color. In aqueous solutions, nickel occurs as the octahedral, hexahydrate ion $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ (Windholz 1983) which is poorly absorbed by most living organisms (Sunderman and Oskarsson 1991).

Nickel subsulfide is formed during the roasting and smelting of nickel ore and may be shipped as the matte for further processing, but does not have any other significant commercial uses (Tien and Howson 1981).

Data on the chemical properties of nickel and some important nickel compounds are shown in Table 3-2.

Table 3-2. Physical and Chemical Properties of Nickel and Compounds^a

Property	Nickel	Nickel oxide	Nickel sulfate	Nickel chloride
Molecular weight	58.69	74.69	154.75	129.60
Color	Silvery	Green	Greenish-yellow	Golden yellow bronze
Physical state	Solid	Solid	Solid	Solid
Melting point	1,455°C	1,984°C	840°C	1,001°C
Boiling point	2,730°C	No data	No data	Sublimes at 973°C
Density	8.90 g/cm ³	6.67 g/cm ³	3.68 g/cm ³	3.55 g/cm ³
Odor	No data	No data	Odorless	None
Odor threshold:				
Water	No data	No data	No data	No data
Air	No data	No data	No data	No data
Solubility:				
Water	1.1 mg/L at 37°C ^b	1.1 mg/L at 20°C	293 g/L at 0°C	642 g/L at 20°C
Organic solvent(s)	No data	No data	Insoluble in ether and acetone; 0.2 g/L at 35°C in ethanol; 1.1 g/L at 35°C in methanol	Soluble in ethanol
Partition coefficients:				
Log K _{ow}	No data	No data	No data	No data
Log K _{oc}	No data	No data	No data	No data
Vapor pressure	1 mmHg at 1,810°C	No data	No data	1 mmHg at 671°C
Henry's law constant	No data	No data	No data	No data
Autoignition temperature	No data	No data	Nonflammable	Nonflammable
Flashpoint	No data	No data	Nonflammable	Nonflammable
Flammability limits	No data	No data	Nonflammable	Nonflammable
Conversion factors	No data	No data	No data	No data
Explosive limits	No data	No data	No data	No data

^aAll information obtained from HSDB 1996 except where noted.^bIshimatsu et al. 1995.^cData is for the hexahydrate.

Table 3-2. Physical and Chemical Properties of Nickel and Compounds^a (continued)

Characteristic	Nickel acetate	Nickel nitrate	Nickel subsulfide
Molecular weight	176.80	182.72	240.19
Color	Green	Green	Pale yellowish
Physical state	Solid	Solid	Solid
Melting point	Decomposes	56.7°C ^b	790°C
Boiling point	16.6°C	136.7°C ^b	No data
Density	1.798 g/cm ³	2.05 g/cm ³ ^c	5.82 g/cm ³
Odor	Acetic odor	No data	No data
Odor threshold:			
Water	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	17 weight% at 68°C	2385/L at 00°C ^c	517 mg/L at 37°C ^b
Organic solvent(s)	Insoluble in alcohol	Insoluble in alcohol ^b	
Partition coefficients:			
Log K _{ow}	No data	No data	No data
Log K _{oc}	No data	No data	No data
Vapor pressure	No data	No data	No data
Henry's law constant	No data	No data	No data
Autoignition temperature	No data	No data	No data
Flashpoint	No data	No data	No data
Flammability limits	No data	No data	No data
Conversion factors	No data	No data	No data
Explosive limits	No data	No data	No data